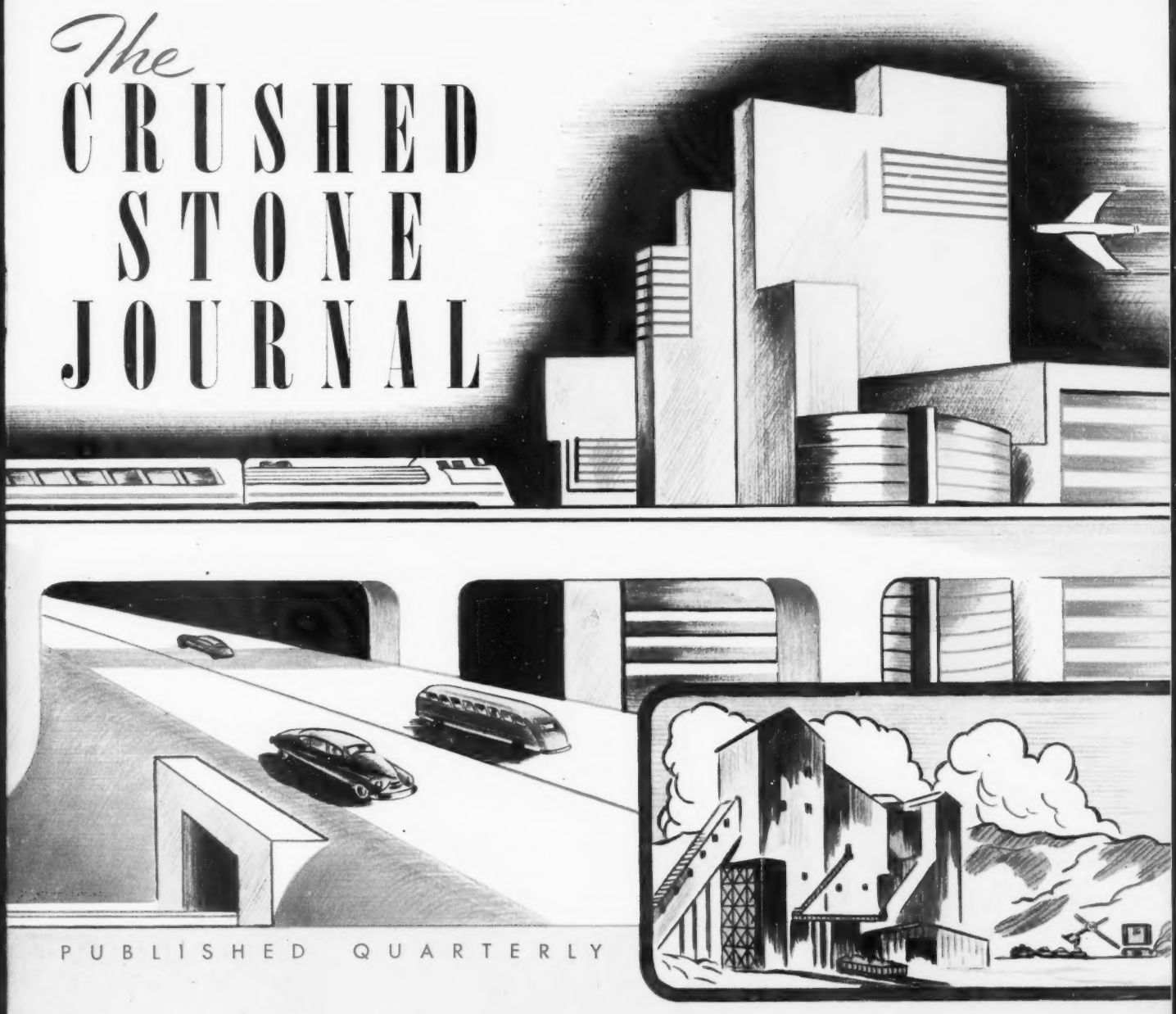
The CRUSHED STONE JOURNAL



PUBLISHED QUARTERLY

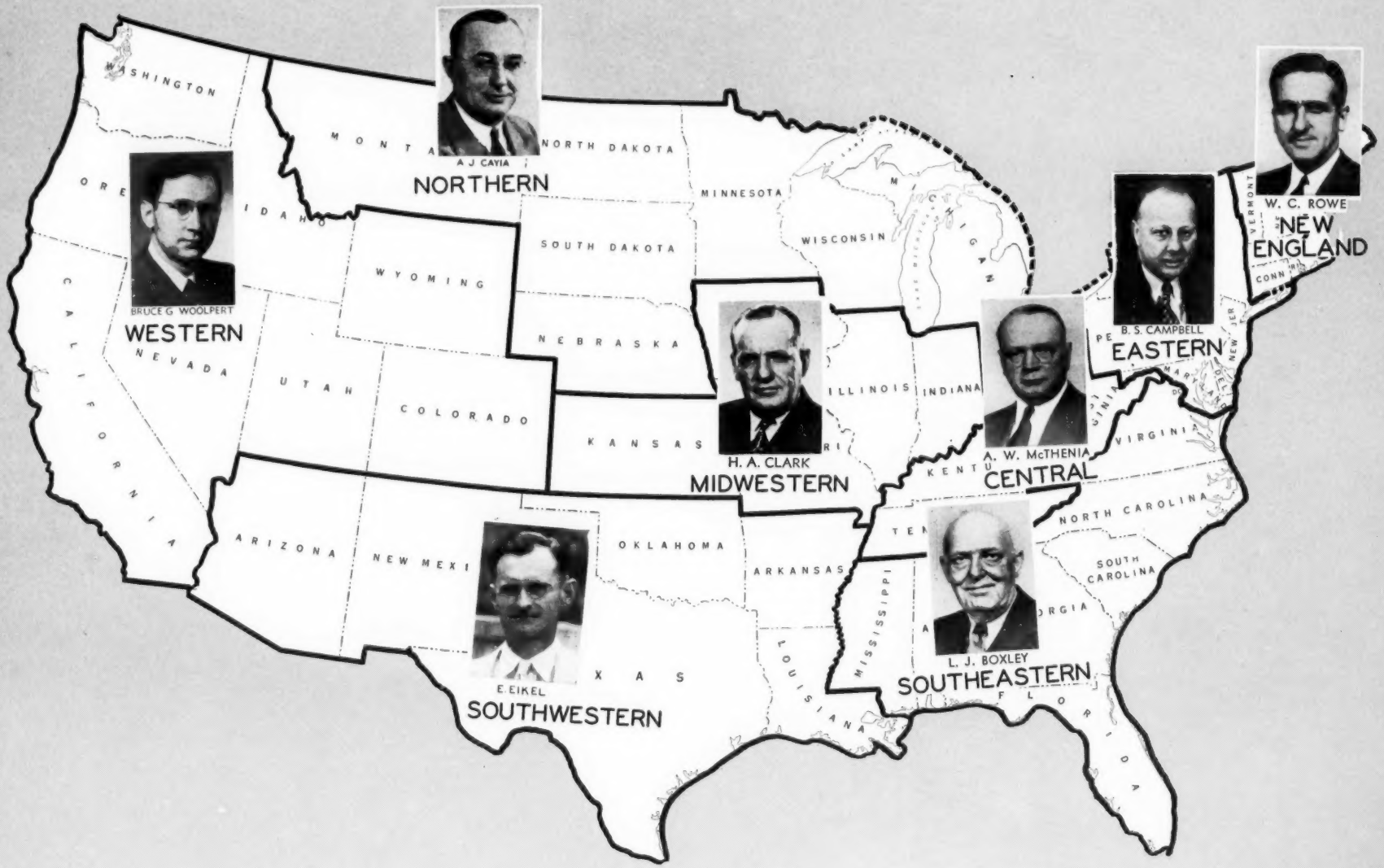
In This Issue

March 1954

- 37th Annual Convention Draws Over 1500
- Developments in the Present Day Rigid Pavement
- Discussion of Plant Mixes
- AGC Survey Shows Highway and Building Construction to Rise

OFFICIAL PUBLICATION · NATIONAL CRUSHED STONE ASSOCIATION

MAP SHOWING REGIONS AND REGIONAL VICE PRESIDENTS FOR 1954
NATIONAL CRUSHED STONE ASSOCIATION



The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

NATIONAL CRUSHED STONE ASSOCIATION

1415 Elliot Place, N. W.
Washington 7, D. C.

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T. C. COOKE

President
Lynn Sand and Stone Co.
Swampscott, Mass.

●

Elected President
NATIONAL CRUSHED STONE ASSOCIATION
by the Board of Directors
Chicago, Ill.

February 21, 1954

B. R. MALONEY

E. I. du Pont de Nemours & Co.
New York, N. Y.

●

Elected Chairman
MANUFACTURERS DIVISION
at its Annual Meeting
Chicago, Ill.

February 23, 1954

THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XXIX No. 1 PUBLISHED QUARTERLY MARCH 1954

37th Annual Convention Draws Over 1500

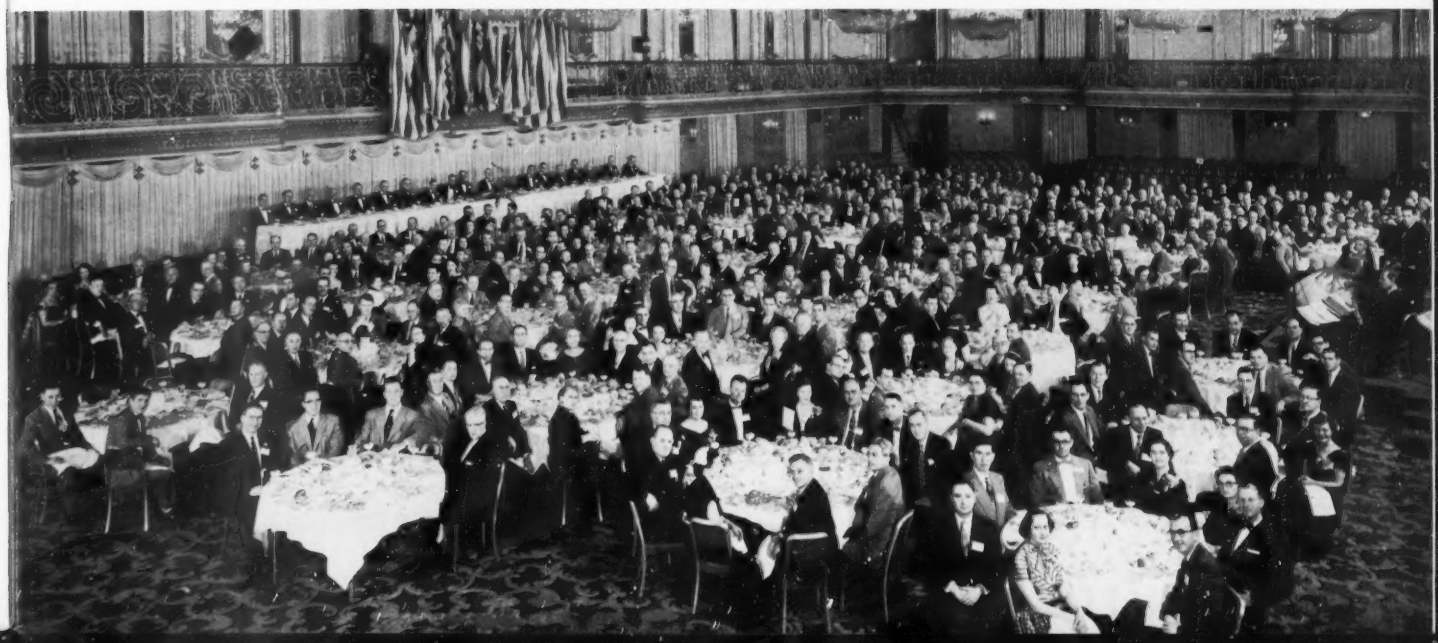
THE 37th Annual Convention of the National Crushed Stone Association, held at the Conrad Hilton in Chicago on February 22, 23, and 24, 1954, was considered by those in attendance the greatest in the long history of NCSA Annual Meetings; and with good reason judging from the highly complimentary observations made during the Convention period and by the many congratulatory letters which have been received. Not since our association with NCSA have we witnessed such spontaneous, obviously sincere, and widespread expressions of approval. Let it be quickly added that this highly gratifying result could have been accomplished only through the harmonious and effective efforts of the many who were involved one way or another in developing the program and handling the arrangements for the meeting.

The Convention Arrangements Committee, under the capable Chairmanship of Otho M. Graves, gave much time and effort to the development of a program which proved of outstanding interest and enjoyment. That the Exposition was by all odds the most attractive and comprehensive yet held, reflects the painstaking work by the Manufacturers Division Exposition Committee, under the able Chairmanship of Irwin F. Deister, and the fine cooperation on the part of exhibitors in the planning and preparation of the exhibits.

The ladies in attendance were enthusiastic in their praise of the program and arrangements which had been planned for their pleasure; and certainly the success of this program was contributed to in very large measure by our three gracious and charming Hostesses, Mrs. H. A. Clark, Mrs. M. E. McLean, and Mrs. I. F. Deister.

Something new was added to the cocktail party and buffet dinner on Monday evening by providing dance music throughout the affair. This innovation

Annual Banquet, National Crushed Stone Association, The Conrad Hilton, Chicago, Ill., February 24, 1954



was met with such enthusiastic response as to strongly suggest that it become a regular feature of the Monday evening program.

All previous records were broken by the 37th Annual Meeting—the total official registration was 1522, exceeding the previous high, established in Chicago in 1952, by over 150; the number of exhibitors increased over the previous high, as did the total floor area occupied by exhibits; and last, but by no means least important, we were fortunate in having the largest turnout of ladies in our history.

The session for operating men and equipment manufacturers held on Tuesday morning again gave evidence of being the most popular convention session. Four excellent talks dealing with basically important operating problems were presented by a group of operators from the Association's membership, particularly selected for their wide knowledge of the subjects presented. The concluding part of the operating session was devoted to a consolidated presentation of "Tricks of the Trade," consisting of brief descriptions of how difficult operating problems have been solved in a unique and unusual way. All in all, the session for operating men was intensely interesting and should prove of great practical value.

Hostesses for Ladies Entertainment. Left to right: Mrs. M. E. McLean, Mrs. I. F. Deister, Mrs. H. A. Clark

This wealth of useful material is now in the last stages of preparation for printing and will be distributed to members in the near future.

A great deal of thought and planning went into the development of the program for operating men. To G. D. Lott, Jr., and his committee, much credit is due.

Ladies Luncheon, The Conrad Hilton, Chicago, Ill., February 23, 1954

Director of U. S. Bureau of Mines Presents Safety Awards

At the general luncheon on Wednesday, we were especially honored to have J. J. Forbes, Director of the United States Bureau of Mines, present the Safety Awards for the NCSA Safety Contest. In addition, it was a distinct privilege to have as our guests from the Bureau, James Westfield, Chief of the Health and Safety Division, and Seth T. Reese, Chief, Accident Analysis Branch of the Health and Safety Division, under whose immediate supervision the Safety Contest is conducted. To Director Forbes goes our grateful appreciation for his willingness to leave his busy desk to assist us in giving public recognition to the winners in the Safety Contest.

Welcome Back, Mr. Judkins!

Among our distinguished guests at the 37th Annual Meeting were Myrton Judkins and C. E. Marston, both of Judkins Limited, Nuneaton, England. We had the pleasure of meeting Mr. Judkins at our Convention in 1952 when he attended as the official representative of the British Institute of Quarrying. In response to our invitation to appear on the Convention program, he presented slides of his operation in England which strikingly illustrated the possibility of making a quarry property truly attractive. It was an added pleasure to have with us his Co-Director, C. E. Marston, and we do hope, particularly in view of the fact that Judkins Limited has now joined the Association, that they will find it possible to attend our Convention each year.

T. C. Cooke Becomes New President of NCSA

The Board of Directors, which had been elected by mail ballot prior to the Annual Convention, held its organizing meeting on Sunday afternoon, February 21, 1954, and proceeded as provided for in the By-Laws to elect the President, the Executive Committee, and the other officers.

Immediately following announcement by Chairman Krause that nominations for the office of President were in order, A. L. Worthen, past President of the Association, spoke as follows:

> "I am very happy to have the opportunity to place in nomination for the Presidency of the National Crushed Stone Association a man whom I have known for a great many years. As a matter of fact, I have known him since he was a small boy. When I entered the crushed stone business over 43 years ago, his father was an executive of the company for which I went to work, and I enjoyed very much working with him. Some years later his father left

Meeting of Newly Elected NCSA Board of Directors

EXECUTIVE COMMITTEE

of the

NATIONAL CRUSHED STONE ASSOCIATION

for the year 1954

T. C. COOKE
Lynn Sand and Stone Co.
Swampscott, Mass.
President
National Crushed Stone Association

J. REID CALLANAN
Callanan Road Improvement Co.
South Bethlehem, N. Y.

H. A. CLARK
Consumers Co.
Chicago, Ill.

WILSON P. FOSS, III
New York Trap Rock Corp.
New York, N. Y.

OTHO M. GRAVES
General Crushed Stone Co.
Easton, Pa.
Honorary Member

H. C. KRAUSE
Columbia Quarry Co.
St. Louis, Mo.

G. D. LOTT, JR.
Palmetto Quarries Co.
Columbia, S. C.

B. R. MALONEY
E. I. du Pont de Nemours & Co.
New York, N. Y.

A. W. MCTHENIA
Acme Limestone Co.
Fort Spring, W. Va.

RUSSELL RAREY
Marble Cliff Quarries Co., Columbus, Ohio

our company and formed a corporation of his own. In 1927 that company took out membership in the National Crushed Stone Association and has been a member ever since.

"When the gentleman I have in mind was still a young man his father died, leaving his son to assume the responsibilities of the family corporation. The son was elected to the Board of Directors of this Association in 1942, has served as a Regional Vice President, and in 1945 was elected to the Executive Committee on which he served two terms. In 1952 he was again elected to the Executive Committee and is at this time a member of that Committee. He is a very capable quarry operator who is and always has been very much interested in this Association. His company throughout the long period of its membership, has continuously been a staunch supporter of our organization.

"Gentlemen, it gives me a great deal of pleasure to place in nomination for President of this Association T. C. Cooke, President of the Lynn Sand & Stone Company, Swampscott, Massachusetts."

Mr. Cooke was unanimously elected, followed by whole-hearted and enthusiastic applause. In accepting the Presidency of the Association Mr. Cooke said he greatly appreciated the honor which had been conferred upon him, and that he would do his utmost, with the help of the Board, the Executive Committee, and the staff, to effectively continue the fine work which the Association is doing.

Re-elected Treasurer
JAMES SAVAGE
Buffalo Crushed Stone Corp., Buffalo, N. Y.

In tribute to Retiring President Krause, Mr. Foss said he had the very distinct pleasure during the last two years of working with him on a variety of tasks which he knew were enormously time-consuming, and that Mr. Krause had devoted himself to those tasks with unflagging interest. On the motion of Mr. Foss the Board then gave a rising vote of thanks and appreciation to retiring President Krause for the splendid work which he had done while serving as President during the last two years.

In responding, Mr. Krause expressed his deep and sincere thanks for the vote of appreciation by the Board. He said that during his entire administration he had been extended every possible cooperation and that if his administration had been successful it was largely due to the very splendid assistance he had received not only from the membership as a whole but also from the Association staff. Retiring President Krause said it had been a real pleasure to work with and for the Board and that he thanked them very much for their helpfulness.

Election of Executive Committee and Other Officers

The Board then proceeded to select the seven elected members of the Executive Committee. Eleven candidates were placed in nomination and, by secret ballot, the seven receiving the highest number of votes were declared elected. In addition, Otho M. Graves was re-elected an Honorary Member of the Executive Committee. The full personnel of the Executive Committee, with the President of NCSA and the Chairman of the Manufacturers Division ex officio members, is as follows:

Executive Committee

T. C. Cooke, Lynn Sand & Stone Co., Swampscott, Mass., *Chairman*
J. R. Callanan, Callanan Road Improvement Co., South Bethlehem, N. Y.
H. A. Clark, Consumers Co., Chicago, Ill.
W. P. Foss, III, New York Trap Rock Corp., New York, N. Y.
Otho M. Graves, General Crushed Stone Co., Easton, Pa.
H. C. Krause, Columbia Quarry Co., St. Louis, Mo.
G. D. Lott, Jr., Palmetto Quarries Co., Columbia, S. C.
B. R. Maloney, E. I. du Pont de Nemours & Co., New York, N. Y.
A. W. McThenia, Acme Limestone Co., Fort Spring, W. Va.
Russell Rarey, Marble Cliff Quarries Co., Columbus, Ohio

Elected as Honorary Members of the Board were:

H. E. Rodes, Nashville, Tenn.
Stirling Tomkins, New York, N. Y.
Harold Williams, Boston, Mass.

Also the following officers were unanimously re-elected for the ensuing year:

James Savage—Treasurer
A. T. Goldbeck—Engineering Director
J. E. Gray—Field Engineer
J. R. Boyd—Administrative Director and Secretary

B. R. MALONEY
E. I. du Pont
de Nemours & Co.
New York, N. Y.
Chairman
Manufacturers Division

T. C. COOKE
Lynn Sand and
Stone Co.
Swampscott, Mass.
President
National Crushed
Stone Association

EXECUTIVE COMMITTEE

of the

MANUFACTURERS DIVISION

National Crushed Stone Association

for the year 1954

I. F. DEISTER
Deister Machine Co.
Fort Wayne, Ind.

L. A. EIBEN
Northern Blower Co.
Cleveland, Ohio

R. D. KETNER
General Electric Co.
Schenectady, N. Y.

WAYNE W. KING
W. S. Tyler Co.
Cleveland, Ohio

NEWLY ELECTED TO MANUFACTURERS DIVISION BOARD

E. T. EGGERS
American Steel & Wire Div.
Cleveland, Ohio

J. M. HUME
Pettibone Mulliken Co. p.
Chicago, Ill.

H. R. STICKEL
White Motor Co.
Cleveland, Ohio

B. R. Maloney Becomes New Chairman of the Manufacturers Division

At the Annual Meeting of the Manufacturers Division, held at luncheon on Tuesday, February 23, with over 200 in attendance, B. R. Maloney was unanimously and enthusiastically elected Chairman of the Manufacturers Division to succeed Irwin F. Deister.

The report of the Nominating Committee submitted by its Chairman, J. Craig McLanahan, was unanimously adopted, resulting in the election of the following to the offices as designated:

Chairman

B. R. Maloney, E. I. du Pont de Nemours & Co., New York, N. Y.

Vice Chairmen

L. A. Eiben, Northern Blower Co., Cleveland, Ohio
R. D. Ketner, General Electric Co., Schenectady, N. Y.
Wayne W. King, W. S. Tyler Co., Cleveland, Ohio

Representatives on NCSA Board

I. F. Deister, Deister Machine Co., Fort Wayne, Ind.
L. A. Eiben, Northern Blower Co., Cleveland, Ohio

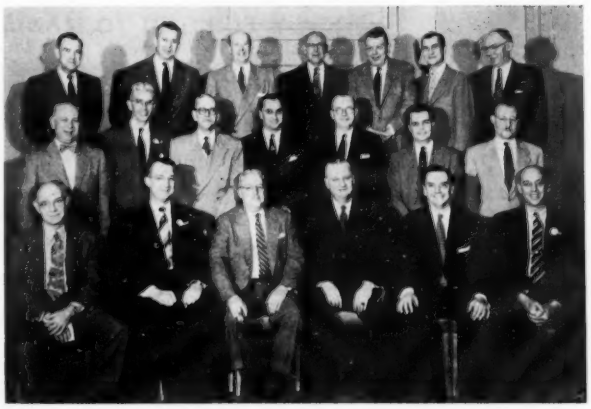
Manufacturers Division Annual Business Meeting Luncheon, The Conrad Hilton, Chicago, Ill., February 23, 1954

Directors

J. B. Bond, Nordberg Mfg. Co., Milwaukee, Wis.
W. E. Collins, Jr., Atlas Powder Co., Wilmington, Del.
R. M. Dickey, Bucyrus-Erie Co., South Milwaukee, Wis.
C. R. Dodge, Northwest Engineering Co., Chicago. Ill.
E. T. Eggers, American Steel & Wire Division, Cleveland, Ohio
G. D. Fraunfelder, Easton Car & Construction Co., Easton, Pa.
E. S. Gill, Gill Rock Drill Co., Lebanon, Pa.
J. W. Hardesty, Baldwin-Lima-Hamilton Corp., Lima, Ohio
H. R. Harrington, Goodyear Tire & Rubber Co., Inc., Akron, Ohio
G. C. Holton, American Cyanamid Co., New York, N. Y.
J. M. Hume, Pettibone Mulliken Corp., Chicago, Ill.
G. H. Keppel, C. G. Buchanan Crushing Machinery Div., Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa.
K. F. Lange, Link-Belt Co., Chicago, Ill.
H. W. Newton, Barber-Greene Co., Aurora, Ill.
L. A. Rhodes, Jeffrey Manufacturing Co., Columbus, Ohio
W. A. Rundquist, Pioneer Engineering Works, Inc., Minneapolis, Minn.
A. E. Schneider, Stedman Foundry & Machine Co., Inc., Aurora, Ind.
C. D. Smith, Joy Manufacturing Co., Pittsburgh, Pa.
V. L. Snow, Euclid Division, General Motors Corp., Cleveland, Ohio
H. R. Stickel, White Motor Co., Cleveland, Ohio
Gilfry Ward, American Manganese Steel Div., American Brake Shoe Co., Chicago, Ill.
C. S. Weber, Thew Shovel Co., Lorain, Ohio

Attention is directed to the fact that in addition to elected Directors, the Chairman, Vice Chairmen, Representatives on the NCSA Board of Directors, and President of NCSA are ex officio members of the Board of the Manufacturers Division. Further, that B. R. Maloney, newly elected Chairman, will serve as an ex officio member representing the Manufacturers Division on the Board of Directors and the Executive Committee of NCSA.

Chairman-Elect Maloney, in accepting the Chairmanship, said he was very appreciative of the opportunity to be of service; that it was an honor and a privilege which he accepted most humbly knowing that it was going to be a difficult assignment to match the performances of the long line of able men who had preceded him.



Members of New Board Manufacturers Division Present at 1954 Annual Meeting

Top Row, left to right:

G. H. KEPPEL, Sales Manager, C. G. Buchanan Crushing Machine Division, Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa.

K. F. LANGE, Sales Manager, Link-Belt Co., Chicago, Ill.

J. M. HUME, Assistant Director of Sales, Pettibone Mulliken Corp., Chicago, Ill.

H. W. NEWTON, Assistant Sales Manager, Barber-Greene Co., Aurora, Ill.

W. E. COLLINS, JR., Director of Sales, Atlas Powder Co., Wilmington, Del.

C. D. SMITH, Manager Distributor Sales, Joy Manufacturing Co., Pittsburgh, Pa.

G. C. HOLTON, Manager, Explosives Department, American Cyanamid Co., New York, N. Y.

Middle Row, left to right:

L. A. RHODES, Manager of Sales, Pulverizer and Crusher Division, Jeffrey Manufacturing Co., Columbus, Ohio.

G. D. FRAUNFELDER, Director Engineering and Research, Easton Car & Construction Co., Easton, Pa.

H. R. HARRINGTON, Assistant Manager, Belting Sales, Industrial Products Division, Goodyear Tire & Rubber Co., Inc., Akron, Ohio.

GILFRY WARD, President, American Manganese Steel Division, American Brake Shoe Co., Chicago, Ill.

A. E. SCHNEIDER, President and General Manager, Stedman Foundry & Machine Co., Inc., Aurora, Ind.

J. W. HARDESTY, Sales Manager, Baldwin-Lima-Hamilton Corp., Lima, Ohio.

C. S. WEBER, Advertising Manager, Thew Shovel Co., Lorain, Ohio.

Bottom Row, left to right:

J. R. Boyd, Secretary, Manufacturers Division, National Crushed Stone Association, Washington, D. C.

L. A. EIBEN, President, Northern Blower Co., Cleveland, Ohio.

WAYNE W. KING, Assistant Vice President, W. S. Tyler Co., Cleveland, Ohio.

B. R. MALONEY, Manager, New York Explosives Office, E. I. du Pont de Nemours & Co., New York, N. Y.

I. F. DEISTER, Vice President, Deister Machine Co., Fort Wayne, Ind.

R. D. KETNER, General Electric Co., Schenectady, N. Y.

At the close of the Manufacturers Division Annual Meeting, past Chairman McLanahan said he had a little task to perform which gave him a great deal of pleasure. He then presented to Mr. Deister, in behalf of the Division, the gavel which he had used during the past two years in presiding as Chairman, and on which the following had been inscribed:

IRWIN F. DEISTER
Chairman 1952-1953
Manufacturers Division
National Crushed Stone Association
In grateful appreciation of services rendered

In retiring from the Chairmanship of the Division, Mr. Deister expressed his thanks to Mr. Krause and the Board of Directors of NCSA for their fine cooperation during his term of office. He also expressed appreciation to the Executive Committee and to the other committees of the Division for their helpfulness during his administration. He commended the Washington staff for their cooperation and assistance and said he was most grateful for the opportunity which the Division had given him to serve as their Chairman.

L. W. Shugg, Director of Exhibits

Announcing . . .

38TH ANNUAL CONVENTION

NATIONAL CRUSHED STONE ASSOCIATION

● NETHERLAND PLAZA HOTEL
CINCINNATI, OHIO
FEBRUARY 7-8-9, 1955

PLAN NOW TO ATTEND

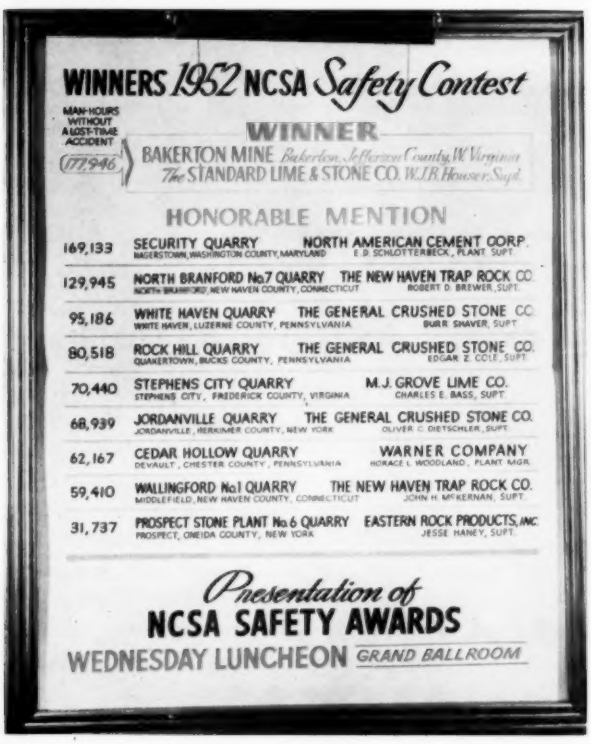
Accident Prevention Committee

Standing, left to right:

W. J. WISE, Vice President, Southwest Stone Co., Dallas, Texas.
H. H. KIRWIN, Treasurer, Eastern Rock Products, Inc., Utica, N. Y.
S. B. FLEMING, Safety Engineer, New York Trap Rock Corp., Newburgh, N. Y.
H. C. KRAUSE, President, Columbia Quarry Co., St. Louis, Mo.
H. E. RAINER, Manager, Federal Crushed Stone Corp., Buffalo, N. Y.
B. G. WOOLPERT, Vice President, Granite Rock Co., Watsonville, Calif.

Sitting, left to right:

T. W. JONES, Production Manager, New Haven Trap Rock Co., New Haven, Conn.
C. A. GUSTAFSON, Superintendent, Plant No. 1, Callanan Road Improvement Co., South Bethlehem, N. Y., *Chairman, NCSA Accident Prevention Committee*
H. F. YOTTER, Insurance Supervisor, General Crushed Stone Co., Easton, Pa.


WINNERS 1952 NCSA Safety Contest
MAN-HOURS WITHOUT A LOST-TIME ACCIDENT
1,771,946
WINNER
BAKERTON MINE Bakerton, Jefferson County, W. Virginia
The STANDARD LIME & STONE CO. W. J. B. Houser, Supt.
HONORABLE MENTION
169,133 SECURITY QUARRY NORTH AMERICAN CEMENT CORP.
HAGERSTOWN, WASHINGTON COUNTY, MARYLAND E. D. SCHLOTTERBECK, PLANT SUPT.
129,945 NORTH BRANFORD No. 7 QUARRY THE NEW HAVEN TRAP ROCK CO.
NORTH BRANFORD, NEW HAVEN COUNTY, CONNECTICUT ROBERT D. BREWER, SUPT.
95,186 WHITE HAVEN QUARRY THE GENERAL CRUSHED STONE CO.
WHITE HAVEN, LUZERNE COUNTY, PENNSYLVANIA BURR SHAVER, SUPT.
80,518 ROCK HILL QUARRY THE GENERAL CRUSHED STONE CO.
QUAKERTOWN, BUCKS COUNTY, PENNSYLVANIA EDGAR Z. COLE, SUPT.
70,440 STEPHENS CITY QUARRY M. J. GROVE LIME CO.
STEPHENS CITY, FREDERICK COUNTY, VIRGINIA CHARLES E. BASS, SUPT.
68,939 JORDANVILLE QUARRY THE GENERAL CRUSHED STONE CO.
JORDANVILLE, HERKIMER COUNTY, NEW YORK OLIVER C. DIETSCHLER, SUPT.
62,167 CEDAR HOLLOW QUARRY WARNER COMPANY
DEVAULT, CHESTER COUNTY, PENNSYLVANIA HORACE L. WOODLAND, PLANT MGR.
59,410 WALLINGFORD No. 1 QUARRY THE NEW HAVEN TRAP ROCK CO.
MIDDLEFIELD, NEW HAVEN COUNTY, CONNECTICUT JOHN H. McKERNAN, SUPT.
31,737 PROSPECT STONE PLANT No. 6 QUARRY EASTERN ROCK PRODUCTS, INC.
PROSPECT, ONEIDA COUNTY, NEW YORK JESSE HANEY, SUPT.
Presentation of
NCSA SAFETY AWARDS
WEDNESDAY LUNCHEON GRAND BALLROOM

Winners of NCSA Safety Contest for 1952

Top Row, left to right:

HORACE L. WOODLAND, Plant Manager, Cedar Hollow Quarry, Warner Co., Philadelphia, Pa.
OLIVER C. DIETSCHLER, Superintendent, Jordanville Quarry, General Crushed Stone Co., Easton, Pa.
BURR SHAVER, Superintendent, White Haven Quarry, General Crushed Stone Co., Easton, Pa.
JESSE HANEY, Superintendent, Prospect Stone Plant No. 6, Eastern Rock Products Inc., Utica, N. Y.
EDGAR Z. COLE, Superintendent, Rock Hill Quarry, General Crushed Stone Co., Easton, Pa.
ROBERT D. BREWER, Superintendent, North Branford No. 7 Quarry, New Haven Trap Rock Co., New Haven, Conn.

Bottom Row, left to right:

C. A. GUSTAFSON, Superintendent, Plant No. 1, Callanan Road Improvement Co., South Bethlehem, N. Y., *Chairman, NCSA Accident Prevention Committee*
CHARLES F. BASS, Superintendent, Wallingford No. 1 Quarry, New Haven Trap Rock Co., New Haven, Conn.
W. J. B. HOUSER, Superintendent, Bakerton Mine, Standard Lime and Stone Co., Baltimore, Md.
J. J. FORBES, Director, U. S. Bureau of Mines, Washington, D. C.
PAUL M. HEDLEY, Director of Industrial Relations, North American Cement Corp., New York, N. Y.

J. J. Forbes, Director of the U. S. Bureau of Mines Congratulates W. J. B. Houser, Superintendent of the Bakerton Mine, Standard Lime and Stone Co., on Winning NCSA Safety Trophy

Developments in the Present Day Rigid Pavement[1]

By A. T. GOLDBECK

Engineering Director
National Crushed Stone Association
Washington, D. C.

SOME thirty years ago I had the pleasure of appearing before this organization to present the results of the Bureau of Public Roads researches on concrete pavements. At that period we had already made deformation measurements on pavements; we had a division on soils and even then had advocated the use of a granular layer under concrete when the natural subgrade had more than 5 per cent linear shrinkage and 20 per cent moisture equivalent. We didn't even think of mud pumping in those days, for that was not then a problem; but here are the reasons we advanced for suggesting a "blanket layer" of granular materials under the pavement:

1. To furnish a layer whose characteristics are unaffected by moisture.

2. To provide more uniform pavement support, primarily during periods of localized freezing of the subgrade.

3. To increase somewhat the load carrying value of the pavement through the increased thickness provided by the blanket layer.

4. It is possible, as indicated by some of our measurements, that the actual moisture content in the underlying subgrade is somewhat reduced thereby.

Those statements are good today, but to them we could now add:

5. To prevent the removal of the subgrade from under the pavement due to the action of mud pumping.

[1] Presented at the meeting of the Association of Highway Officials of North Atlantic States, Washington, D. C., March 11, 1954

Pavement Warping—Development of Design Theory

We were also familiar with temperature and moisture warping or curling of pavements and with the stresses thereby produced when the pavement was bent down by wheel loads into contact with the subgrade. I have always been justly proud of the fact that the first theoretical analysis of pavement stresses was made in my office by the late Dr. H. M. Westergaard, an analysis which is still good if a proper kind of granular subgrade is used to prevent mud pumping. If mud pumping occurs, this will destroy one of his assumptions regarding the subgrade support. Mr. McDonald, former Chief of the Bureau of Public Roads, deserves a lot of credit for his foresight in engaging Dr. Westergaard to perform this original theoretical analysis.

Early Pavement Tests

Others also were diligently seeking the facts regarding pavement design in those days, notably Clifford Older of Illinois with his classic Bates Road test, the forerunner of some of our present day accelerated traffic investigations such as the Maryland Test Road and others. There, for the first time, the significance of fatigue of concrete was established and, incidentally, the fatigue tests performed by the Illinois laboratory under H. F. Clemmer still give us the best information we have on that subject. And so—even thirty years ago a lot of basic information had been obtained in an effort to develop a rational way to design a concrete pavement so as to take account of the various forces to which the pavement would be subjected.

It is my purpose today to trace some of the developments which have come about in pavement design as they have been made possible through research and through experience with actual pavements.

Evolution of Pavement Design

Many of you recall our old cross-section design. The slab was laid to full width without a center longitudinal joint, perhaps with some crown in the subgrade, but with more crown in the pavement surface, with the result that we had a full sectioned pavement with no center joint, thinner at the sides than at the center. Longitudinal cracks were frequent and were considered inevitable. Little thought was given to the reasons for these cracks, but almost simultaneously Clifford Older, in Illinois, and the Bureau of Public Roads, at its then Arlington Experiment Station, found that wide slabs actually left the subgrade, due primarily to temperature differentials between the top and bottom of the slab. The edges, particularly at the corners, curled up at night and left a void space at the edge. During the day the reverse was true; then the center humped up and the slab was supported at its edges by the subgrade. Under such conditions, the dead weight of the slab and the action of passing loads created a transverse bending moment which exceeded the resisting moment of the concrete, and failure in the form of a longitudinal crack occurred.

Calculations showed that great slab thickness would be needed to prevent this type of failure and so a longitudinal joint down the middle was suggested. This center joint relieved the slab of all transverse bending stress at the center and transferred the location of maximum stress to the edges and corners.

Many pavements were only 16 ft wide and an 18 ft width was considered adequate. However, much of the heavy traffic was forced to the edge of the pavement where it was thinnest and weakest. Corner cracking under such circumstances became frequent and, in an effort to bring about a "balanced" design which would permit the pavement to carry wheel loads with equal safety everywhere, the edge was thickened. And so then we had a pavement which was safe against longitudinal cracking, for the crack was built into the pavement, and a pavement which also was much safer against edge and corner failure. The Bureau of Public Roads stress measurements of thirty odd years ago showed that wheel loads along the extreme edge produced the maximum stress in the pavement and that if the wheel was moved in only 6 in. the edge stress was much relieved. Subsequent tests have confirmed those original findings. This influence of the location of the heavy wheel load on the slab stress is a highly significant fact which is made use of in present day design.

It was found that continuous stretches of concrete pavement developed transverse cracks and a lot of thought was given to this subject and to ways of minimizing their occurrence. If a concrete pavement were built on roller bearings and without end restraint, it could expand and contract freely due to temperature and moisture with no direct stress producing effect, although there might be an indirect cracking effect due to temperature differential from top to bottom of the slab.

The direct force which produces transverse cracking is the force of friction between the slab and the subgrade, and tests were made many years ago, and since then confirmed by several investigators, which showed that the type of subgrade and its smoothness had great influence on the forces of friction. Also the amount of movement of the slab was important—the greater the movement the greater the friction. The values for coefficient of friction extended up to above 2.0 but, owing to the action of traffic, it is likely that the value for the friction coefficient rarely exceeds 1.5. No doubt it frequently is less than this, but 1.5 has been widely used, especially in calculations for the necessary amount of longitudinal steel.

When a transverse crack occurs in the concrete, the longitudinal steel alone must resist the tension produced by the contraction or shrinkage of the slab and, to prevent its failure, the steel must be strong enough to pull over the subgrade that portion of the slab extending from the crack to the free end. A widely used formula was set up many years ago to express this idea and it is still the method most used for determining not only the amount of longitudinal steel, but also the weight and spacing of center tie bars, for obviously these bars must be strong enough to resist the lateral forces of subgrade friction as the slab contracts laterally. The greater the length of slab, the greater must be the cross-section of the steel, for a long slab requires a greater pull than a short slab to slide it over the subgrade. I shan't bother you with formulas or calculations, for they are to be found in the literature.

Traffic has been increasing with unpredicted intensity, not only in volume but, of even greater importance from the structural design standpoint, it has been increasing in magnitude of wheel load. The number of large size motor vehicles likewise

has increased and they are moving at high speeds, even higher than was possible in the automobile traffic of years ago. Safety soon became, and still is, a problem of major importance and greater lateral clearance between vehicles became paramount. This separation was accomplished by increasing the width of each traffic lane. The 8 or 9 ft lane of years ago has now become 10, 11, or preferably 12 ft. One change leads to another and it was found that with the wider traffic lanes there was no necessity for heavy vehicles to travel along the extreme edge of the pavement. Corner cracking became almost a non-existent problem and now, instead of the thickened edge design, there is a most decided trend toward a uniform cross-section—a very natural development.

But this advent of heavy wheel loads introduced problems which formerly did not exist except to a negligible amount. I refer to the problem of mud pumping. The Westergaard theory is premised on the support of the slab on a subgrade of homogeneous material offering uniform support until the slab is bent under wheel loads. Water finds its way to the subgrade, particularly at joints, but along the shoulders as well, and the subgrade is softened just at the point where softening is undesirable because, at a joint, the slab has no resistance to bending. A wheel load bends it down more at this spot than at other points in the slab and hence there is a kneading of the subgrade under passing traffic which destroys its original structure. It becomes softer as more water is mixed with it, and pretty soon under heavy wheel loads the excess water is forced out from under the slab and up through the open joint or crack. Due to the high velocity of the water it carries fine particles with it and so-called mud pumping has started. The void space under the slab becomes even greater and now we have a slab with no support under the corner, or perhaps under the entire end of the slab.

Some individuals have assumed that the failure of slabs which thereby resulted proved that Westergaard and other theorists were all wrong, but that was not the case. Westergaard used a quantity (k) in his calculations which he called the "modulus of subgrade reaction" and his formulas indicated the need for very little change in pavement thickness with rather large changes in k. Mud pumping was not common and the possible value of a granular sub-base was not universally realized. By most engineers such a sub-base was looked upon as an unwarranted expense. Hence it was not uncommon for engineers to lay their pavements directly on the subgrade, however plastic it might be. They are not to be condemned for this practice, for the extremely heavy traffic conditions which made a sub-base necessary did not exist. But they surely exist now and anyone who does not use a suitable granular sub-base on a plastic subgrade under a concrete pavement for present day heavy traffic is subjecting himself to future condemnation.

And so—the concrete pavement, just like the motor vehicle, has gone through stages of development and even though still not perfect, it renders excellent service and its imperfections and their cure constitute a challenge to present day engineers and their successors.

During the past decade the durability of concrete subjected to freezing conditions and to ice removing agents has been tremendously improved by the use of air entraining agents. This can be considered one of the outstanding developments in the improvement of concrete pavements in recent years.

All of this leads us to a consideration of at least some of the essential features of the concrete pavement as they have been developed up to the present. It, of course, is foolhardy for anyone to attempt to outline these features, but here they are all set up for your criticism.

Certain Essential Features of the Concrete Pavement

1. Grade Line

Build the grade line well above the ditch line and, in a level country, well above the level of the surrounding terrain. Many a mile of concrete pavement in the old days was built level with the ground adjacent to the ditches and such pavements were frequently inundated. This subgrade remained saturated for a long time during which the pavement carried some heavy traffic and serious damage was done.

2. Subgrade

A soils survey is essential, for the nature of the subgrade material will indicate:

(a) Whether it may have to be removed in spots and replaced with more suitable granular and non-plastic materials

(b) The need for a blanket layer

(1) To prevent mud pumping

(2) To add strength by decreasing the deflection of the pavement slabs

(c) The need for drainage and the kind of drainage to use

3. Blanket Layer

Except on a stable, well drained, granular subgrade, a suitable blanket course is needed. Such a layer, to prevent mud pumping, must not contain any appreciable amount of minus 200 material, probably much less than given in the following conclusion from a mud pumping study in Ohio, which reads: "A subgrade soil even under the most severe intensities of loadings recorded in Ohio will not pump if: (a) the sand and gravel content (material retained on the No. 200 sieve) is in excess of 55 per cent, the soil is fairly well graded and (b) the plasticity index is 6 or less." This blanket layer must be stable when wet; its particles should be at least large enough to prevent their being carried out by rushing water having high velocity under passing traffic.

The sub-base must be an effective blanket layer which will hold the subgrade in place and prevent the fine particles from filtering upward through that layer. To determine the suitability of such a layer, soils engineers have introduced the term "piping ratio." The piping ratio is the ratio of the diameter of the sieve opening which will pass 15 per cent of the filter or blanket, or sub-base material. to the sieve opening which will pass 85 per cent of the subgrade material. This ratio should not exceed 5.0. The theory is that sub-base material coarser than this might allow the subgrade soil to pass or filter upward through it and thus produce a layer of pumpable material immediately under the pavement slab. As a general rule, well graded concrete sand or stone screenings will meet this piping ratio requirement.

There is still another matter regarding the sub-base layer. Should it be impermeable or should it allow water to pass through it? Well, personally, I don't like the idea of water filtering down through this layer to the subgrade, for such water surely will make the subgrade softer and less resistant to deformation. On the other hand, the water reaching the sub-base from above should not be trapped there, and that could happen, especially in a trenched type of construction. We shouldn't create an underground lake beneath the pavement. Accordingly, it would seem that a granular sub-base material might well be impervious in its lower level next to the subgrade and more open in its upper half, thus making it drainable and hence less liable to mud pumping because of its coarseness. This drainable portion of the sub-base could well extend under the shoulders to the side ditches. At least it should be provided with drainage.

The question of how thick a granular sub-base should be is still not answered. Some engineers have the idea that thickness should be provided to distribute the transmitted pressures and thus increase the load carrying capacity of the slab by increasing the bearing value of the base or, expressed in terms of the current theory, to increase the Westergaard k value. However, as pointed out previously, a great increase in k or subgrade stiffness does not result in much greater load carrying capacity of the slab.

Some engineers have claimed that relatively few inches of sub-base are sufficient to act as a filtering layer to prevent mud pumping and if this is true, then a few inches would suffice. It is a fact that severe failure of the Maryland Test Road did not take place until mud pumping began. In the case of the Idlewild airport, 3 in. of dolomite screenings were tried as a sub-base material, but it was found that this was not enough for, under the action of construction equipment, the sub-base became churned up with the subgrade. When the thickness of screenings was increased to 6 in., this churning action did not take place and satisfactory construction resulted. The subgrade was a sandy silt pumped out of the bay and it could well be that a less favorable subgrade might demand a thicker blanket layer.

This use of a granular sub-base is about the most important development in concrete pavement design in recent years, and it will do much to lengthen the useful life of the pavement.

Pavement Slab

1. Width

Now as to the slab itself, as pointed out, in the interest of safety, pavement slabs have been widened so that we have reached a traffic lane of 12 ft and a two lane width of 24 ft, with a center joint to eliminate longitudinal cracking.

2. Cross Section

Also, largely because of this width and the infrequency of extreme edge travel, the thickened edge seems to be no longer necessary and a slab of uniform thickness is fast becoming the rule. The thickness of the slab depends on the weight and frequency of wheel load and the edge thickness may still be calculated by Westergaard's methods, using a unit stress of half the modulus of rupture so as to minimize failure due to fatigue, and also by other methods more recently suggested by Dr. Pickett and other engineers in England and Sweden. However, good as these methods undoubtedly are, they should be used as an aid to the judgment and the engineer's observation of existing pavements and his considered judgment should sway him in his determination of slab thickness.

Sometimes, as in airport design, service behavior examples are not available and then calculations for thickness are very important. But even here, because of the large tire imprint area, the question of just how much load is carried on adjoining slabs presents some uncertainty, and so the use of sound judgment is still important.

What is considered good practice for pavement thickness? Well, the old 9-6-9 pavement for heavy traffic of Clifford Older's day has now developed into a 10 in. slab of uniform thickness generally laid on a granular sub-base. Thicknesses of 8, 9, and 10 in. are used, the thickness being governed by the traffic intensity. So we have reached the stage, through a process of development, of slabs generally 11 or 12 ft wide and 8, 9, or 10 in. thick. That leaves the question of slab length.

3. Slab Length

The investigations of many years ago showed us that concrete had certain inherent properties which inevitably would result in more or less frequent transverse cracking, depending upon circumstances. Concrete is relatively weak in resistance to bending with a modulus of rupture roughly of the order of 600-700 psi and a resistance to direct tension of roughly half this amount. It is a rigid material which can't be bent much without cracking. It shrinks when it dries out completely to the amount of roughly 0.05 per cent and expands when wet roughly 0.01 per cent.

It suffers thermal change in length with changing temperatures, dependent largely upon the coefficient of expansion of the coarse aggregate, but approximately of the order of 0.000003 to 0.000007, and generally assumed at 0.000005 inch per inch per degree F. These physical constants and also the friction of the subgrade must be considered in these matters of transverse cracking and of frequency of transverse joints in the pavement, whether they be expansion or contraction joints. This whole subject of joints has been discussed many times and there does not seem to be any closer approach to a universally accepted answer to the proper spacing than existed thirty years ago.

The coarse aggregate seems to play a major role in controlling the spacing of transverse cracks. Plain, unreinforced concrete slabs made with crushed limestone, trap rock, or crushed granite seldom develop intermediate transverse cracks when built with slab lengths of 25 ft; slabs built of gravel and crushed gravel of normal grading and a maximum size of 1 in. or greater may have a slab length of 20 ft. Siliceous gravel, not over 3/4 in. in maximum size, or blast furnace slag plain concrete pavement slabs should not exceed 15 ft in length to avoid intermediate cracking.

4. Expansion Joints

Some engineers have publicly stated that so far as expansion joints are concerned they would use only two such joints, one at each state line. That answer to the expansion joint spacing problem makes me uncomfortable. In one state having this policy, there were over 3000 blow-ups in one year. That surely imposes an element of danger. It brings up the picture of a bus loaded with people traveling at high speed and a blow-up occurring with such violence as to throw the vehicle out of control. It seems to me that an expansion joint is a desirable safety feature, undesirable as it may be from the standpoint of slab faulting and slab maintenance.

There is a trend away from the use of transverse expansion joints. A few years ago, 27 states used them and 18 did not. Now 17 states use them and 25 do not. As stated, from the safety standpoint I do not like this trend and, furthermore, trends are not always in the right direction.

I shan't go into the theory of slab length as determined by transverse cracking and spacing of joints. These may be controlled by the before mentioned physical constants, but the present day

practice points to the following trends judging by an analysis of a survey of state practices in 1952.

Of the states using expansion joints, there is a wide range in spacing, varying all the way from 60 up to 1000 ft. Quite evidently, engineers are not of one mind on this subject.

Expansion joint widths of 3/4 and 1 in. are used generally, but one state uses a 1/2 in. width with an 80 ft spacing of expansion joints. If there were no contraction joints in between, an unreinforced slab generally would crack, although there are some very noticeable exceptions to this rule. Many of you have undoubtedly seen some uncracked plain slabs over 100 ft in length. I don't think I shall risk an opinion regarding expansion joint spacing. Local conditions of temperature and aggregates undoubtedly must influence this spacing. Observation and service behavior as influenced by different expansion joint spacings are better guides than any theory of which I am aware.

5. Transverse Contraction Joints

In 1952, 38 states used transverse contraction joints and some states did not use them at all. A weakened plane joint, generally 1/4 to 3/8 in. thick predominated, having a depth of 2 to 2 ½ in. and in some cases a depth of up to 1/2 the slab depth. These joints are poured with bituminous or with rubber compound material. A few states have experimented with sawed joints, both transverse and longitudinal, to create a weakened plane. The saw cut is 1 1/2 to 2 1/2 in. deep and the cut is made preferably as soon as the concrete is sufficiently hard to permit of sawing. There has been some difficulty in maintaining a seal in sawed joints because of their small volume, but they make possible an exceptionally smooth riding surface.

Obviously, in reinforced pavements there is an interrelationship between the spacing of contraction joints and the amount of steel necessary to prevent wide cracks from forming. The greater the spacing of joints, the higher must be the amount of longitudinal steel. The economic length of slabs, considering the initial cost of joints and steel, extends up to 70 ft and, considering the fact that it is more costly to maintain a joint having large movement, it seems possible that the economical slab length is in the neighborhood of 60 ft. Some analyses indicate, however, that transverse joint spacings not in excess of 40 ft might be desirable to minimize the difficulty of joint maintenance.

6. Load Transfer Devices

In general, load transfer devices are used both across expansion joints and weakened plane contraction joints, and they quite generally consist of 3/4 to 1 in. dowels, 12 to 24 in. long and spaced 12 to 15 in. center to center.

A few states have used 1 1/4 in. dowels and, in recognition of the fact that rusting sometimes results in seizure, one state is now using a 1 1/4 in. dowel partly encased in stainless steel tubing. This dowel is reported to be successful. Special types of load transfer devices are also used.

It is my opinion that the ordinary round dowel bar is not a particularly good load transfer device. It tends to rust and bind; it may cause grinding or crushing of the concrete, thus causing the so-called "funneling" of the concrete and final bending of the dowel due to the excessive span length thus produced. Too frequently, also, the dowel has not been properly installed because of the difficulty of maintaining it in its desired position, parallel with its neighbor.

I believe that dowels can be improved in design. Their purpose is to transfer load across the joint and not provide resisting moment. But, by its very design we force the dowel to bend under each heavy wheel load and thus undesirable funneling of the concrete is produced. Surely our designers should analyze this problem more closely and I have no doubt they can come forth with a better design and a better way of using the dowel as a load transfer device.

The expansion joint is a weak point in pavement design which needs improvement so that it will remain watertight and so that the load transfer element will continue to function during the useful life of the pavement. I think both these things can be accomplished.

7. Steel Reinforcement

It will be recalled that at one time, perhaps as a result of the Bates Road Test, steel reinforcement, if it could be called by that name, consisted of continuous marginal bars, greased to break their bond. They really acted as dowels across joints or across cracks wherever cracks occurred. However, it was early recognized that reinforcing steel bonded to

the concrete played a rather important role in the concrete pavement. Its role is not to increase the bending resistance of the slab to any extent, but rather to prevent cracks from widening after they form.

An experiment made in 1921 on the Columbia Pike in Arlington, Virginia, was very enlightening in showing the effect of different amounts of longitudinal steel. Expansion joints were placed 200 ft apart in all test sections. It was reported by the speaker that:

"In sections which have from eight to fourteen 3/4 in. round deformed rods placed longitudinally, transverse cracks occur at frequent intervals a very few feet apart. These cracks, however, are very fine and in some sections are barely discernible. Sections which have eight 3/4 in. rods are not cracked as frequently as those having fourteen 3/4 in. rods. One section having four 1 in. rods is cracked slightly less than sections having eight 3/4 in. rods. Sections which have reinforcing varying from four 3/4 to four 1/2 in. rods are free from fine transverse cracks but have wide open cracks, similar to those found in plain concrete sections but spaced at greater distance, 60 to 70 ft as compared with 40 to 50 for plain concrete. Sections which are reinforced with 25 and 50 lb of mesh per 100 sq ft have no fine cracks but do have open cracks spaced at greater distances than would ordinarily be found in plain concrete. In order to discover the cause for the action of these several sections, the cracks were opened in a number of instances, thus exposing the steel.

"It was found that in those sections having eight or more 3/4 in. deformed round bars, no change in diameter of the bars had occurred. In the section reinforced with four 1 in. bars, slight reductions in diameter were found. In the section having four 3/4 in. bars, the diameter was reduced to 5/8 in. In sections having eight 1/2 in. rods, the diameter has been reduced to approximately 3/8 in., while in still another section having only four 1/2 in. bars, the bars had completely broken with a reduction in diameter to about 1/4 in. In sections reinforced with mesh to the extent of 25 and 50 lb per 100 sq ft, the mesh was completely broken at the cracks. From these sections it is strongly indicated: (1) That longitudinal steel up to a certain amount does increase the spacing of the transverse cracks and these cracks will open on contraction. (2) That longitudinal steel above this amount might produce fine transverse cracks, spaced in some cases only a few feet apart."

Obviously, there is a relationship between the proper amount of longitudinal steel and the spacing of joints and the greater the distance between joints, the greater must be the amount of steel because the steel must be strong enough to slide the slab over the subgrade in times of cracking. The principles established in 1921 for longitudinal steel design still hold and, as far as I am aware, there have not been any developments which have changed the methods for longitudinal steel design then advocated.

Of late years experimental stretches of pavement have been built containing continuous longitudinal steel, extending over long lengths of pavement, one of the ideas being to produce a pavement which would eliminate joints and their troubles, and also to make for smoother riding qualities. These several pavements in general are behaving in like manner. Transverse cracks are sometimes only a foot apart as might have been predicted because high stress in the steel induces high stress in the concrete. It can hardly be said that these continuously reinforced pavements have offered any advance in concrete pavement design, not yet at least. However, they should be observed in the future and their advantages and disadvantages weighed carefully.

8. Concrete Characteristics

Perhaps there has been no greater improvement made in highway concrete subjected to severe climate than has been the introduction of air entrainment. There is no question whatever that air entrainment has vastly improved concrete durability and its resistance to the action of salts used for ice removal. This indeed has been a very important development.

Concrete for pavements must still have high bending resistance, even though the slab is supported more rigidly by the use of a sub-base.

It is still desirable to recognize the difference in aggregate characteristics in connection with joint spacing. The expansion and contraction of concrete is almost identical with that of the coarse aggregate and some coarse aggregates expand twice as much as others. Aggregates having a high thermal coefficient of expansion produce high warping stresses

(Continued on Page 24)

Discussion of Plant Mixes[1]

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In any discussion of plant mixes I feel it in order to preface the discussion with some brief comments on the foundation upon which the plant mix is to be placed. While the subject of foundation courses is itself a lengthy one, certain fundamentals cannot be repeated and emphasized too often.

Foundation Courses

It is the subgrade, sub-base, and base courses that carry the load of moving vehicles on our roads and streets. The plant mix surface is merely a protective covering or roof over the foundation courses. This should be kept in mind whether the proposed work is new construction, reconstruction, or the resurfacing of existing pavements. In the case of new or reconstruction, soil and traffic surveys should be made to determine the necessary total thickness of base and pavement needed to carry the load.

In the case of resurfacing, each project should be carefully inspected to determine if there is an adequate foundation. With old asphaltic pavements this often can be accomplished by visual inspection. If the pavement is rough, dried out, or highly crowned with few cracks then resurfacing is in order to obtain a new, smooth riding pavement. On the other hand if there is a considerable amount of cracking, particularly of the alligator type, or numerous depressions accompanied by cracking, base failure is indicated. A new 2 or 3 in. plant mix surface course cannot be expected to correct this condition.

Flexible Base

The preferable type of base to use under a flexible surface, is a flexible base. If good rock or gravel are economically available, untreated crusher run or waterbound bases may be constructed which are quite satisfactory. If the aggregate is of a borderline type, that is questionable as to plasticity or clay content, the material may be mixed in place or through a batch type pug mill with an asphalt emulsion, cut-back or other asphaltic residuum. The amount of bituminous material used should be just sufficient to overcome plasticity and aid in compaction of the base aggregate. Lime and portland cement have also been used for this purpose with varying degrees of success. The advantage of a bituminous treatment is the retarding of water action and maintaining the flexibility of the base.

Subsealing Concrete Pavements

Portland cement pavements may need subsealing prior to resurfacing with plant mix. Rocking slabs and/or pumping are usually the physical signs of pavements that need subsealing. In some areas this has been reduced to a minimum by the use of asphalt treated bases under the concrete. While on the subject of portland cement concrete pavements I would like to call attention to the false belief still held by a few engineers that for heavy duty pavements only concrete will prove satisfactory. There are innumerable examples of asphaltic pavements carrying maximum possible loads that could be cited to refute this belief. The New Jersey Turnpike, now under construction, is of the heavy duty asphalt type. This turnpike is 118 miles in length and is designed to carry heavy traffic from the south to New York City. The saving effected through the selection of this type of construction was $50,000 per mile.

Asphaltic Concrete Base

The last type of base construction I am going to mention is the asphaltic concrete base, actually a plant mix with an average top size aggregate of 1 1/2 in. This type of base is particularly useful in railway track removal projects. It is quickly laid, durable, and cuts the time that the road or street is closed to traffic. The usual design is 6 in. of base, laid in two courses and a 2 or 3 in. plant mix surface course.

[1] Presented at the Fourth Asphalt Institute Forum, Carson City, Nevada, November 29, 1951

Plant Mix or Asphaltic Concrete

With these very sketchy comments on foundation courses I will pass on to plant mixes, the subject of this paper. While it is true that some of our asphalt treated base courses are types of plant mix, the remainder of this discussion will deal with the plant mixes that form the actual wearing surface of the pavement.

The general term plant mix may mean mixtures of graded mineral aggregates with cut-back asphalts, asphalt emulsions, slow curing oils, or asphalt cements. This discussion will be limited to mixtures of graded mineral aggregates and asphalt cement. The definition of an asphalt cement is a refined asphalt, or a combination of a refined asphalt and flux, suitable for paving purposes. It has a normal penetration of between 40 and 300. An asphaltic concrete is defined as a plant mix of asphalt cement and coarse graded mineral aggregate. Hence in this discussion the terms plant mix and asphaltic concrete become synonymous, since by definition the term asphaltic concrete refers to a type of paving mixture and not a specific method of mixing and spreading. The definition of asphaltic concrete as stated herewith is national in scope.

Now let us take our plant mix or asphaltic concrete apart and see what it is composed of. We find that under the specifications used in Nevada it is composed of 92 or more per cent of mineral aggregate and the remainder asphalt cement. The asphalt cement has no inherent stability and is actually a lubricant. Its purpose is to bind the particles of mineral aggregate together, prevent intrusion of moisture into the mix and foundation courses, and to facilitate compaction. So it is the mineral aggregate which must withstand the attrition of traffic and resist displacement and should be given primary consideration in design of our plant mixes.

Mineral Aggregate

Mineral aggregate is usually split on a No. 8 standard sieve, all above being considered coarse aggregate and all below fine aggregate. That portion of the fine aggregate passing a No. 200 mesh standard sieve is considered a mineral filler or dust.

Coarse aggregate should be hard and tough having a loss in the Los Angeles rattler test of not over 45 per cent. Materials showing a lower percentage of loss should be used where economically available. To obtain maximum stability in the mix, coarse aggregate should be crushed rock, crushed gravel, or a combination of both. However, if the crushed material can be obtained only at a premium, satisfactory mixes can be and have been produced using uncrushed gravel of the proper surface texture and gradation. Coarse aggregate should be hydrophobic, that is, showing a surface preference for asphalt instead of water, thus reducing tendency to stripping. It must be clean and free of thin elongated pieces.

Fine aggregate may be either manufactured crusher fines or a natural sand. It must be clean, hard-grained, sharp, and show a surface preference for asphalt instead of water. A blend of coarse sand and fine sand may be used provided they are proportioned to give a well-balanced grading.

It is a generally accepted fact that to obtain maximum desirable stability and density in an asphalt pavement, a well-graded interlocking coarse aggregate should be used. To retain the maximum points of contact between the particles of coarse aggregate, the percentage of fine aggregate should not be such as to spread the particles apart. In carrying out this sound principle of design, I believe there is too often a tendency to overlook the importance of the stability of the fine aggregate itself and its ability to carry and hold the proportion of asphalt designed for it. In other words, fine aggregate should not be considered as merely "something" to fill in the voids of the coarse aggregate.

Particle shape and surface characteristics are just as important in fine aggregate, even down to the minus 200 mesh or "flour" size as in the coarse aggregate. As previously mentioned asphalt like any oily derivative is a lubricant and if the fine aggregate is composed essentially of rounded or spherical shaped particles the resultant action is similar to that of minute ball bearings, tending to reduce the stability of the composite paving mixture. If in addition, as is generally the case, these spherical particles have a smooth or glassy surface, they do not retain the percentage of asphalt indicated by the grading and surface area. Therefore, if the full percentage of asphalt is used as required by the composite grading, there is a tendency for a portion of it to leave the particles of fine aggregate. This enriches the amount of asphalt in the coarse aggregate sizes, producing instability or "bleeding" in the pavement surface. If the asphalt content is lowered a "dry" mix of potentially shorter life is the result.

Another important characteristic of a fine aggre-

gate or blend of fine aggregates is the grading. It has been found both through laboratory research and practical experience that when the grading of the composite mineral aggregate for any given plant mix, plotted on a semi-log paper, produces a curve that is smooth and at least slightly concave, good stability may be expected. If the grading of the composite mineral aggregate is unbalanced, having too large a percentage on any one of the finer sieve sizes, the grading curve will show a "hump" and the mix will tend toward lower stability.

For city work the importance of the proper fine aggregate is even greater than on country highways. Thin surfaces and "feathering" are frequently indicated requiring smaller top size coarse aggregate and a proportionate larger percentage of fines.

Mineral Filler

Mineral filler has been used in asphalt mixes primarily to obtain increased density and stability. Some years ago efforts to obtain stability were confined largely to the use of mineral filler. This was particularly true in the design of sheet asphalt. Since this type of mix calls for only fine aggregate, the use of a filler has served a useful purpose particularly in the case of fine aggregate that did not come up to standard in regard to grading and sharpness.

With the development of the asphaltic concrete type of mix it was at first thought necessary to add an appreciable amount of filler to attain density and stability. However, in recent years it has been found possible to obtain excellent density and stability with careful selection of the coarse and fine aggregate components, and proper proportioning of the two. The percentage of material passing the 200 mesh has become of lesser importance and not essential to density and stability. Sections 41 and 43 of the Nevada Department of Highways Standard Specifications require a minimum of 5 per cent passing the 200 mesh sieve. Generally, sufficient minus 200 mesh material is naturally present in the fine aggregate to meet this requirement, particularly if it is manufactured crusher fines.

If mineral filler should be needed it may be either a natural or a manufactured product with at least 60 per cent passing the No. 200 mesh sieve. Limestone dust, hydrated lime, and portland cement are good fillers. Many rock dusts and gravel fines are also satisfactory as fillers. The mineral filler proposed for use should be laboratory tested prior to use. Suggested tests are void content, affinity for asphalt, and microscopic examination for angularity.

Open grade or Virginia mixes do not require any minus 200 mesh material. They are composed essentially of coarse aggregate of good interlocking characteristics, hence of high stability. The percentage of aggregate passing the No. 8 sieve may be as low as 15 and there may be 0 per cent passing the No. 16 mesh sieve. This type of mix has been used on both country and city roads and exhibited high stability under heavy traffic as well as good resistance to skidding.

Occasionally it may be found that the only coarse or fine aggregate economically available is border line in its affinity for asphalt. In such cases the addition of a small percentage of an alkali reacting filler, such as limestone dust, hydrated lime, waste lime, or some similar material may be found quite beneficial. The percentage added would vary from 2 to 6 per cent depending upon the material used. In these cases the filler is not used to make up a deficiency in fines but as a catalytic agent promoting the adherence of the film of asphalt to the aggregate surfaces.

Grade of Asphalt Cement

This brings us to the question of the grade of asphalt cement to use. It was mentioned earlier that by definition, asphalt cements range in penetration from 40 to 300. Since density and stability are a function of the combined mineral aggregates exclusive of the asphalt cement, then theoretically it would not seem to matter what penetration asphalt cement is selected for the mix. This theory holds true on most of the state and county roads in the open country where traffic right from the start is more or less of a continuous flow in one direction in the traffic lanes. City traffic presents a somewhat different problem. Here we have stopping and starting, cross and turning traffic. Asphalt cements of 200 and 300 penetration which are quite satisfactory on the open road, at times cause difficulty on city streets or parking and loading areas when a mix containing these asphalts is laid in hot weather. It may not cool or "set" below a critical point of temperature before being opened to heavy traffic, consequently we are apt to get marking and some displacement, particularly at turning points and intersections. Therefore, it is recommended that the asphalt cement used in plant mixes for surfacing city streets or parking areas be generally of the 85 to 100 grade of penetration and under some condi-

tions of hot weather construction, the 60 to 70 grade may be advisable. While 200 to 300 penetration asphalt has been used in open graded mixes on state highways, I would not generally recommend a grade higher than 150 penetration for this type of mix on city streets for reasons previously mentioned.

Percentage of Asphalt Cement

The methods of determining the percentage of asphalt cement to be used in a mix will not be discussed here. They are outlined in detail in the several state specifications and elsewhere. The more asphalt that can be used in a mix, the longer the prospective life of the pavement. Therefore, the percentage of asphalt cement specified should be as high as possible, consistent with adequate stability. Dense graded mixes require thin films of asphalt and open-graded mixes require thicker films. The open-graded mixes are composed almost entirely of coarse aggregate of high inherent stability but must be protected from the action of water, hence the thicker film. In effect, asphalt cement is being substituted for the higher surface area fine aggregate.

Under the voidage theory it was formerly believed that, for dense graded mixes, sufficient asphalt should be specified to fill the voids in the composite mineral aggregate. In practice it has been found desirable to have 3 to 5 per cent voids in the pavement, since even after final rolling it has been noted that additional compaction will take place under traffic. If the voids are completely filled with asphalt, bleeding or displacement may occur.

Importance of Mixing Temperatures

Mixing temperatures are highly important in combining the mineral aggregates and the asphalt cement. Generally, the lowest possible mixing temperature should be used consistent with complete coating of the aggregate particles, good workability, and compaction. While the temperature control of both the asphalt cement and aggregate is important, particular care must be taken not to overheat the aggregate. During the mixing process the asphalt cement is spread in a thin film over the aggregate and high temperatures, plus the action of rapid air movement, can quickly oxidize or reduce the penetration of the asphalt cement. For example, on a project constructed about two years ago, a contractor ran his mixing plant with a broken pyrometer on the dryer and without an inspector present either at the plant or on the street. There was no appearance of burned material in the finished pavement. However, cracking developed almost immediately and about 60 samples of the pavement were taken, the asphalt cement being extracted and recovered by the Abson process. The penetration of the original asphalt cement was 92. The penetration of the asphalt cement extracted from the samples ranged from 11 to 22. The project had only been provisionally accepted due to the lack of inspection so the contractor had to repave the entire street.

Asphalts from different sources will at times require a little different mixing temperatures, that is, one asphalt cement may require a little higher temperature for efficient mixing than another. The minimum mixing temperature is based on the viscosity of the asphalt cement. This temperature may be determined by viscosity curve charts and furnished to the user by the State Highway Laboratory or the producer. Several instances have been reported of poor coating of aggregates in plant mixes that were cured by just a little adjustment in mixing temperatures.

Types of Mixing Plants

Mixing plants may be either of the batch or continuous mix type. Excellent plant mixes have been produced by both. Needless to say the plant should have proper drying, screening, and bin facilities for delivering uniform plant mixes. Plant inspection is highly important and should be carried on by trained personnel. A paper could well be written on this subject alone. Time does not permit discussion here.

Type of Plant Mix

The type of plant mix to be used is dependent on the specific job to be accomplished. Generally, on new or reconstruction, dense graded plant mix is used. For the resurfacing of old pavements, asphalt or concrete, either dense graded or open graded mix may be selected. The coarse aggregate in dense graded mixes is usually of 3/4, 1/2, or 3/8 in. top size. Occasionally, for skin patching or feathering, a mix may be required in which all the mineral aggregate will pass a No. 4 sieve. The coarse aggregate in open graded mixes is usually 3/4 or 1/2 in. top size.

For new or reconstruction or roads or streets subject to a large volume of traffic and heavy wheel loads, the 3/4 in. mix is usually selected and laid to

a thickness of 3 in., in two 1 1/2 in. courses. However, on an adequate and tightly bonded base course there is no reason why a 2 in. course should not prove satisfactory. For residential and other lighter travelled streets, the 1/2 in. mix is usually selected and laid to a thickness of 1 1/2 in.

Resurfacing brings in the problem of varying thicknesses depending on the condition of the old pavement. The general rule in determining the maximum size coarse aggregate to use in resurfacing is as follows: For 2 in. thickness or greater, 3/4 in. top size; 1 1/2 in. thickness, either 3/4 or 1/2 in. top size; and for a 1 in. thickness 1/2 in. top size. For any thickness less than 1 in., the 3/8 in. top size aggregate may be used. If the surface of the old pavement is uneven then the thickness of the resurfacing course will vary. The top size mix to be used in that case will depend on the thinnest portion of the surfacing to be placed. For example, if the finishing machine is set for a maximum 2 in. surface and there are rises in the old pavement that will reduce this to 1 in. at certain points, then the 1/2 in. mix should be used to prevent dragging.

For plant mix construction in some areas the use of commercially produced aggregate is not economically feasible. The source of materials then may be selected pits. Good results can be expected if sufficient preliminary tests are made on the pit material and the indicated percentage of asphalt cement accurately controlled. Unless tests of the fine aggregate portion indicate high stability it is recommended that a fairly coarse graded mix be designed with a maximum top size consistent with the thickness of the pavement course to be laid.

Testing

I do not want to conclude this discussion without saying a word in regard to testing. Having been for many years closely connected with materials testing I realize it is vital in any paving program. State laboratories are usually well equipped to make all tests necessary from the basement soil or subgrade to the finished pavement. Cities and other political subdivisions not having laboratory facilities of their own will find that whatever money they can invest in having tests made will pay big dividends in satisfactory work. There is a slogan I would like to quote in closing, "One test is worth a thousand expert opinions."

Developments in the Present Dry Rigid Pavement

(*Continued from Page 19*)

and, likewise, high direct tension during times of falling temperatures. It is now recognized that such aggregates should be used with frequently spaced joints, for otherwise there will be excessive transverse cracking. This growing appreciation of the beneficial effects of aggregates which produce high beam strength and which also have low thermal coefficients of expansion and, therefore, low thermal stresses, may be considered to be a gradual development.

Conclusion

Not too many years ago we had some bad defects in concrete pavements, including:

1. Excessive breakage of slabs under heavy loads due to mud pumping. That defect is now prevented by the use of a proper granular sub-base.

2. We had excessive faulting at the joints due to the pounding effect of heavy wheel loads. This defect was accentuated by mud pumping which resulted in lack of subgrade support and by the ineffectiveness of the load transfer device used. Excessive faulting will be alleviated at least, although not entirely prevented, by the use of adequate sub-base. However, there is still the need for more adequate transfer devices. So-called aggregate interlock cannot be counted on for continuous load transfer at joints.

3. We formerly had excessive scaling and surface disintegration due to salt application for ice removal. Air entrainment has overcome this defect essentially 100 per cent. Experiments made with mineral oil application also give promise of benefit.

In conclusion, there have been some notable developments in concrete pavement design and construction which undoubtedly make this type a much better pavement for all kinds of traffic than it has ever been. It is my belief that the portland cement concrete pavement and also the flexible type of pavement with an asphaltic concrete top can be used with confidence for carrying very heavy traffic, but they both must be designed with attention to those design details which must be taken into account to attain complete success.

AGC Survey Shows Highway and Building Construction to Rise

A HEAVY spurt in highway construction, a more moderate gain in building construction and a dip in heavy engineering projects are in store for the construction industry during the next six months according to a nation-wide survey conducted by The Associated General Contractors of America.

Dominating this picture will be the ever-deepening competition. Although government and private sources forecast a 1954 volume only 2 to 4 per cent less than the all-time high of $46.5 billion achieved last year, the capacity of the industry has expanded so greatly that competition seems bound to increase even if there is an expanding volume of construction.

The reasons for this are made clear in the replies to the survey, conducted among the 122 chapters and 82 national directors of the association. AGC represents more than 6,500 member-firms who annually perform more than 80 per cent of the contract construction in this country as well as a large volume of work overseas.

Contractors who expanded their organizations under the stimulus of war-time demands and during the unprecedentedly good years that followed are fighting to maintain their organizations on their present scale. Their ranks are swelled by new companies that came into existence during this period and are struggling to stay alive, the contractors reported.

With more contractors doing less work during the next six months it is just simple arithmetic that there will be less work per contractor. Possessed of greater capacity, most firms are ranging far and wide in their search for work. In many cases the lowness of bids, often below engineers' estimates, reflects simply a desire to keep up with a large overhead, it was reported in many cases.

Many replies to the survey stated that the lowness of these out-of-state bids is due to a lack of knowledge of local conditions. A growing trend of small contractors to take on bigger jobs, was also reported. Home builders, for instance, because of the decline in residential construction are invading the commercial and heavy construction fields, and building contractors are also picking off heavy engineering projects, the replies stated.

Respondents to the survey said that contractors have not only increased their capacity but also their flexibility. All of it makes, they stated, for increased value to the buyer of construction and further sharpening of contractors' efficiency. The possibility that some will have to reduce the size of their organizations and others will fall by the wayside was seen in many of the replies.

It is a situation which is being carefully analyzed by the officers and members of the association, who engage in all types of construction, such as industrial, commercial, institutional, and residential building; highway, street, and airport construction and other types of earthmoving and paving operations; and heavy engineering work such as dams, waterworks and sewers, pipelines, dredging, canals, bridges, and docks.

Highway Prospects Bright

The brightest spot on the industry's horizon is in the field of highway construction. Fully 46 per cent of the replies in this category forecast an increase in this type of work during the next six months. Another 34 per cent said highway construction would remain at the present level, making a total of 80 per cent predicting an increase or the same high level.

Sixty-one per cent of the respondents said building construction would be either greater or remain at the same high level. Those predicting an increase totaled 35 per cent, those the existing volume, 41 per cent. Thirty-nine per cent saw a decline in this category of construction work between now and August.

In heavy construction the forecast for a decline was made by 54 per cent of the respondents. Seventeen per cent saw an increase ahead, and 29 per cent looked for it to remain stable.

More School Construction

The strongest trend reported in the survey among specific types of projects was in school construction. Twenty-one per cent said there would be more building of schools. Five per cent reported that hospital construction would be increased; making the figure reporting greater institutional construction 30 per cent when church and other institutional structures are included.

An increase in commercial building was forecast in 13 per cent of the replies, and 6 per cent saw a larger volume of industrial projects. In public construction, 16 per cent saw a decline in the six-month period ahead while 7 per cent looked for an increase. Those predicting more private work amounted to 4 per cent.

Regional Picture

Far West

Heavy construction will be hard hit in this area, it was predicted by 75 per cent of the replies from the states of California, Washington, and Oregon and the territory of Alaska. One reply stated that the number of heavy contractors operating in the area had more than doubled since 1945.

An increase or the same high level of highway work was foretold in 77 per cent of the replies, of which, 53 per cent were for an increase. Fourteen per cent looked for an expanded building construction market and 43 per cent for a stable market.

Rocky Mountain

Building and highway work to increase, with heavy construction to remain stable. A definite increase in school construction expected and a decline in federal work. Some increase in commercial and residential work.

Southwest

Declines predicted both in building and heavy construction with highway work increasing. A substantial boom in commercial and school construction and a definite decline in residential building. As a result, home builders are bidding on commercial work and going in for heavy construction as well, replies stated. The construction market has been affected by the drop in the agricultural economy. Good weather has enabled contractors to "catch up" on their work and left them free to bid on more jobs.

Middle West

Highway construction dominates the picture for this area. Sixty-five per cent predicted an increase and 29 per cent expected the volume to remain constant. A decline in this category of construction was expected in only six per cent of the replies.

An increase or the same high level of building construction was forecast by 71 per cent; of that total 36 per cent forecasted an increase. The heavy construction picture will be spotty with some localities very optimistic and others expecting a definite decline. Over-all, heavy construction is expected to rise. Hospitals, churches, schools, and other institutions look very strong as do commercial, industrial, and public building. Somewhat of an increase in defense work and a decline in residential construction.

South

A decline in heavy construction expected by 61 per cent; increases in highway and building construction. Strong points are commercial, school, public, private, and industrial construction. Federal work will decrease as will residential.

One of the replies will serve as an indication of the expansion of the industry in this region.

"Sixty to 70 per cent of the contractors bidding public jobs of $500,000 or over have been in business five years or less," said one respondent. "Fifty per cent have been in business three years or less. Their insufficient cost records and pricing experience and anxiety to grow is causing them to bid dangerously low."

Middle Atlantic

Declines in heavy and building work strongly predicted. Highway work to increase. The drop in building construction is expected by fully 83 per cent of the respondents while that in heavy work is reported by 66 per cent.

New England

The strongest optimism prevails here. Heavy increases in all three categories expected. In highway construction all replies were either for an increase (80 per cent) or for the present continued high level (20 per cent). Eighty per cent predicted either an increase or stabilization of heavy work while 67 per cent were of the same opinion in the building field.

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These associate members are morally and financially aiding the Association in its efforts to protect and advance the interests of the crushed stone industry. Please give them favorable consideration whenever possible.

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A Complete Line of Power Shovels, Draglines, and Cranes

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200 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, Etc.

Murphy Diesel Co.
5317 West Burnham St., Milwaukee 14, Wis.
Engines and Power Units—90 to 246 Hp.; Generator Sets—60 to 154 Kw.; Marine Engines—90 to 225 Hp.; Dual-Fuel Engines—135 to 180 Hp.; Mechanical and Electric Power Simultaneously

National Container Corp. of Ohio
Multi-Wall Paper Bag Division
Jaite, Ohio
Multi-Wall Paper Bags, Sewn and Pasted Style for Packaging Lime, Cement, Plaster, Etc.

New York Rubber Corp.
100 Park Ave., New York 17, N. Y.
Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Nordberg Mfg. Co.
3073 South Chase Ave., Milwaukee 7, Wis.
Symons Cone and Gyratory Crushers; Gyradisc; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens and Grizzlies; Diesel Engines and Diesel Driven Generator and Pumping Units; Mine Hoists; Track Maintenance Machinery

Manufacturers Division—National Crushed Stone Association
(continued)

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 South LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels

Olin Industries, Inc.
Explosives Division
East Alton, Ill.
Dynamite, Black Powder, Blasting Caps, Blasting Supplies

Osgood-General Co.
Osgood St. and Cheney Ave., Marion, Ohio
Power Shovels, Cranes, Draglines, Hoes, Etc., 3/8 to 2 1/2 Cu. Yd.

Pennsylvania Crusher Co.
Liberty Trust Bldg., Broad and Arch Sts., Philadelphia 7, Pa.
Single Roll Crushers, Impactors, Hammermills, Ring Type Granulators, Kue-Ken Jaw Crushers, Kue-Ken Gyracones, Dixie Non-Clog and Standard Hammermills

Pettibone Mulliken Corp.
4710 West Division St., Chicago 51, Ill.
Material Handling Buckets, Clamshells, Draglines, Pullshovels, Dippers, Shovel Dippers, Pumps, Hammermills, Front End Loaders, Bucket Conveyor Loaders, Fork and Bucket Loaders, Speed Swing Loaders, Speed Swing Yard Cranes, Motor Graders, Manganese Steel Castings

Pioneer Engineering Works, Inc.
1515 Central Ave., N. E., Minneapolis 13, Minn.
Jaw Crushers, Roll Crushers (Twin and Triple), Vibrating and Revolving Screens, Feeders (Mechanical, Grizzly, Apron, and Pioneer-Oro), Belt Conveyors, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants and Finishers

Pit and Quarry Publications, Inc.
431 South Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Productive Equipment Corp.
2926 West Lake St., Chicago 12, Ill.
Vibrating Screens

Quaker Rubber Corp.
Division of H. K. Porter Co. of Pittsburgh
Tacony and Milnor Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Radio Corporation of America
Engineering Products Department
Industrial Equipment Section
Front and Cooper Sts., Bldg. 15-1, Camden 2, N. J.
Electronic Metal Detectors

Rock Products
309 West Jackson Blvd., Chicago 6, Ill.

Rogers Iron Works Co.
11th and Pearl Sts., Joplin, Mo.
Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos and Underground Loaders

Screen Equipment Co., Inc.
1754 Walden Ave., Buffalo 25, N. Y.
Seco Vibrating Screens

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screens, Horizontal Screens, Simpli-Flo Screens, Tray Type Screens, Heavy Duty Scalpers, D'Watering Wheels, D'Centegrators, Vibrating Feeders, Vibrating Pan Conveyors

SKF Industries, Inc.
Front St. and Erie Ave., P. O. Box 6731, Philadelphia 32, Pa.
Anti-Friction Bearings—Self-Aligning Ball, Single Row Deep Groove Ball, Angular Contact Ball, Double Row Deep Groove Ball, Spherical Roller, Cylindrical Roller, Ball Thrust, Spherical Roller Thrust; Pillow Block and Flanged Housings—Ball and Roller

Smith Engineering Works
532 East Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Manufacturers Division—National Crushed Stone Association
(concluded)

Stedman Foundry & Machine Co., Inc.
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers, Multi-Cage Limestone Pulverizers, Vibrating Screens

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Talcott, W. O. & M. W., Inc.
91 Sabin St., Providence 1, R. I.
Belt Fasteners, Belt Lacing, Conveyor Belt Fasteners, and Patch Fasteners

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
"Lorain" Power Shovels, Cranes, Draglines, Clamshells, Hoes, Scoop Shovels on Crawlers and Rubber-Tire Mountings. Diesel, Electric, and Gasoline, 3/8 to 2 Yd. Capacities

Torrington Co.
Bantam Bearings Division
3702 West Sample St., South Bend 21, Ind.
Anti-Friction Bearings; Self-Aligning Spherical, Tapered, Cylindrical, and Needle Roller; Roller Thrust; Ball Bearings

Travel Drill Co.
P. O. Box 1124, Raleigh, N. C.
"Travel Drill"—Mobile Drill for Secondary Drilling in Quarries and Open Pit Work

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 North 7th St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N. E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers; Tyler Standard Screen Scale Sieves, U. S. Sieve Series

Unit Crane & Shovel Corp.
6411 West Burnham St., Milwaukee 14, Wis.
1/2 and 3/4 Cu. Yd. Crawler and Rubber Mounted Shovels, Clamshells, Draglines

Universal Engineering Corp.
625 C Ave., N. W., Cedar Rapids, Iowa.
Jaw Crushers, Roll Crushers, Twindual Roll Crushers, Hammermills, Impact Breakers, Complete Line of Crushing, Screening, Washing and Loading Plants, Either Stationary or Portable for Sand and Gravel, Stone, Aggregates or Aglime, Asphalt Plants

Vibration Measurement Engineers
7665 Sheridan Road, Chicago 26, Ill.
Seismographic and Airblast Measurements, Seismological Engineering, Blasting Complaint Investigations, Expert Testimony in Blasting Litigation; Nation-wide Coverage

Werco Steel Co.
2151 East 83rd St., Chicago 17, Ill.
Castings—Manganese, Alloy Steel; Screen Plates—Perforated Steel Screen Sections and Decks; Buckets; Chains; Belt Conveyors, Idlers; Dipper—Shovel; Drop Balls; Wire Cloth; Wire Rope and Related Products

Weston Dump Body Co.
326 S.W. 11th St., Des Moines 9, Iowa
Combination Lime, Sand, and Gravel Body; Special Bodies for Quarry and Pit Work

Wheeler, Delbert
2408 Harrison St., Topeka, Kans.
Wheeler Testing Vibrators

White Motor Co.
842 East 79th St., Cleveland 1, Ohio
On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines, Power Units, Axles, Special Machine Assemblies; All Classes of Service

Technical Publications
of the
National Crushed Stone Association

STONE BRIEFS

No. 1. How to Proportion Workable Concrete for Any Desired Compressive Strength

No. 2. How to Proportion Concrete for Pavements

No. 3. Uses for Stone Screenings

No. 4. How to Determine the Required Thickness of the Non-Rigid Type of Pavement for Highways and Airport Runways

No. 5. The Insulation Base Course Under Portland Cement Concrete Pavements

ENGINEERING BULLETINS

No. 1. The Bulking of Sand and Its Effect on Concrete

No. 2. Low Cost Improvement of Earth Roads with Crushed Stone

No. 3. The Water-Ratio Specification for Concrete and Its Limitations (Supply Exhausted)

No. 4. "Retreading" Our Highways

No. 5. Reprint of "Comparative Tests of Crushed Stone and Gravel Concrete in New Jersey" with Discussion

No. 6. The Bituminous Macadam Pavement

No. 7. Investigations in the Proportioning of Concrete for Highways

No. 8. The Effect of Transportation Methods and Costs on the Crushed Stone, Sand and Gravel, and Slag Industries (Supply Exhausted)

No. 9. Tests for the Traffic Durability of Bituminous Pavements

No. 10. Stone Sand (Supply Exhausted)

No. 11. A Method of Proportioning Concrete for Strength, Workability, and Durability. **(Revised November 1953)**

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Single copies of the above publications are available upon request.

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Manual of Uniform Cost Accounting Principles and Procedure for the Crushed Stone Industry *($2.00 per copy)*